Assessing Public Transit Accessibility and Equity of 10-County Atlanta Region using General Transit Feed Specification (GTFS) Data

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Introduction

With the ever-changing nature of spatial and built environment, transportation authorities have always been in charge to strike a balance between transportation demand and supply. Let alone their traditional job of keeping the transportation infrastructure operational, they have become ever more concerned about transportation equity since the 14^{th} Amendment of the constitution, and the Title VI of the 1966 Civil Rights Act (Karner, 2016; Hart, 2017). Under this act the Federal Transit Administration (FTA) is mandated to conduct service equity analysis, prior to implementing any major services, to ensure that the federal resource are being distributed without having any disparate impacts on the protected groups of people including racial minorities or low income population. However, FTA suggested methods for service equity analysis largely highlight on proximity and ridership as opposed to service quality (Karner, 2015 and Karner and Golub, 2016).

From a conceptual understanding, though equity and accessibility are two fundamentally different issues but at the core, they possess an intricate relationship with each other when it comes down to the question of public transit (Talen and Anselin, 1998). Public transportation systems are usually aimed at serving two distinct groups of users – people who neither can afford a car nor have access to safe and convenient non-motorized alternatives, and people who independently choose not to drive but use public transit (Karner and Golub, 2015). Accessibility, often a debatable concern due to its widely differing reception, but continues to be at the center of contemporary transportation planning efforts. When it comes down to the provision of public transit service, it becomes even more crucial from equity concern as well. Transportation equity can be thought of as an effort to ensure that the service caters to the users irrespective of their spatial or socio-economic background (Blanchard and et. al., 2017). Thus, it becomes more important for the captive riders who have no access to private automobile and thus no way either to travel by public transport or transit system (Langford, Fry and Higgs, 2012; Mavoa, Witten, Pearce and Day, 2009). However, due to its complexity and varying scales of recognition by various Metropolitan Planning Organizations (MPOs) and regional transportation authorities, FTA funded transportation improvement projects are being evaluated on widely varying accessibility matrices.

This paper is intended to assess public transit equity by applying a spatially and temporally sound and resolved accessibility indicator suggested by Karner (2016) and demonstrate its utility with reference to 10-county Atlanta region.

Literature Review

The literature review section tried to explore how equity and accessibility have been historically defined since 1950s, how these two seemingly parallel ideas converge towards the discussion of public transit accessibility, how accessibility has been measured in public transit studies, and how accessibility affects the other spectrum of transportation issues in general.

Transportation, as a derived demand, is heavily influenced by performance of the built environment and the destinations those built environment can offer which leads to the issue of how much accessible a place is from other locations (Hart, 2017). On a general tone, “accessibility is a measure of an individual’s freedom to participate in activities in the environment” (Weibull, 1980). According to Handy and Clifton (2001), accessibility implies the ease of access to desired destination from any particular origin. In broader sense, it is defined as the ease with which desired destinations can be reached given a defined transportation network and land use configuration (Geurs and van Wee, 2004; Guthrie and et. al., 2017).

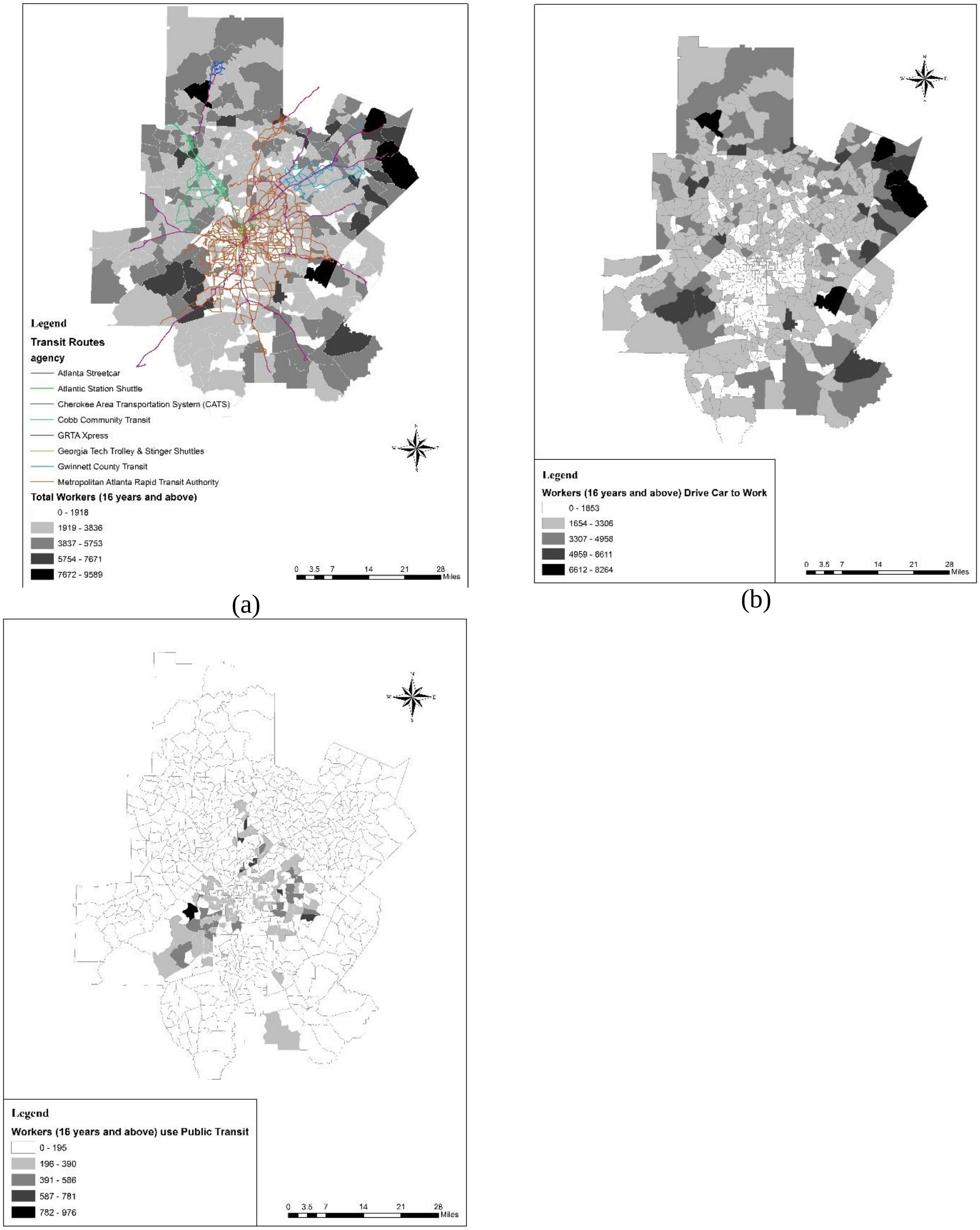
Blanchard and Waddle (2017) admitted the fact that despite attempts being made for a long time to define accessibility there is still a lot of dimensions to address this issue tying with transit equity. MPOs are mandated to assess feasibility of any transportation infrastructure improvement projects with special reference to accessibility being achieved across various groups of people. Apart from the likely accepted concern of reducing congestion on roads, public transit accessibility and equity has been a growing interest among the researchers even long before the Civil Rights Act of 1964 through the enactment of Title VI. Accessibility, as a technical term, was first coined by Stewart (1948) who developed it as ‘population potential’ concept and tended to measure it as a relationship between population and distance. In its broader sense, it is defined as the ease with which individuals can get into desired destinations following a chosen transportation network and associated land use configuration. In other words, the ease with which individual’s ability to reach a desired destination depends on the spatial distribution of activities and the availability of transportation infrastructure around those. For this reason, Guthrie and Fan (2017) sees accessibility as a direct measure of opportunity. One’s access to job implies one’s access to opportunity. However, this shift towards a direct measure of opportunity took place from a very traditional approach of measuring accessibility (counting facilities in an aerial coverage) (Kawn, 1998) to the inclusion of land use and transportation network since 1970s (Davidson, 1977; Cervero, et. al., 2002). Studies during this period acknowledged the direct implication of spatial arrangement of land uses on the structure and performance of transportation services (Wang and Naylor, 2016; Apparicio and Seguin, 2006; Geurs, and et. al. 2003). Further addition of impedance factor as travel time or cost enabled the planners to be concerned with disparate opportunities being provided through transportation infrastructure across various groups of the society which clearly highlighted the equity concerns. As stated by Guthrie and et. al. (2017), “calculating employment accessibility identifies poor neighborhoods with large transit dependent population that also suffer from insufficient transit service.”

Accessibility measures facilitate to assess equity of transit quality and access across socio-economic groups, identify underserved neighborhood, measure transit system demand and performance (Cervero, et. al, 1999; Cervero and Duncan, 2005; Miller, 1999; Blanchard and Waddell, 2017). Concern of accessibility is not limited only at the city level these, the growing concern of accessibility drew attention at regional level as well as. Anderson et. al (2017) used a multi-criteria suitability analysis framework to estimate optimal location for mobility hub that potentially augment public transit accessibility and offer the riders to experience better first and last mile connectivity.

Study area

Atlanta Regional Commission has defied the Atlanta region including 10-counties which has a population of about 4.4 million (ARC, 2016). The counties are namely, Cherokkee, Cobb, Clayton, Dekalb, Douglas, Fulton, Gwinnett, Henry, and Rockdale. The central business district of Atlanta region includes areas of Fulton County. The CBD is connected to surrounding residential and sub-urban locations through a complex multimodal transportation network. This network includes highway systems, bus services, heavy and light rail systems. Public transit providing agencies in this region are namely Atlanta Streetcar, Atlantic Station Shuttle, Cherokee Area Transportation System (CATS), Cobb County Transit (rebranded as CobbLinc), GRTA Xpress, Georgia Tech Trolley, Gwinnett County Transit, and the Metropolitan Atlanta Rapid Transit Authority (MARTA). Per American Community Survey (ACS) (2015), the region houses 2,017,718 workers (16 years and above) with a split between 76% and 3% of them drive alone and take public transit to work respectively.

Figure 1 (a), (b), and (c) show the spatial distribution of workers (16 years and above) with the public transit routes operated by various transit agencies; worker who drive alone to their work, and workers who use public transport to work respectively. Figure 1 (a) and (b) exhibit a visible congruence between the census tracts with high concentration of workers and workers who drive alone to work even though public transit services are available to those census tracts. As per figure 1 (c), High spatial concentration of workers who use public transport to their work are mostly concentrated in the south-west part of the 10-county Atlanta region which is comprised of predominantly low income census tracts. A clear reluctance to use public transport by the workers is noted all over the region except for the census tracts around the downtown and Clayton County.



(c)

Figure 1: Spatial distribution of Workers (a) with a split between workers drive alone to work (b) and use public transport to work (c)

Hass and et. al. (2006) had found that In comparison to other metropolitan areas across the United States, this complex transit network systems of Atlanta could not even offer neither a lower expenditure for household transportation nor housing expenditure. The regional average expenditure on housing and transportation in Atlanta is higher than Boston, Chicago, Dallas, New York, San Francisco. The lower income group (earning less than $20,000 per year) pay more than 60% of their income after housing and transportation which is comparatively lower for the higher income group.

Data and Methods

Data were collected from OpenStreetMap, Atlanta region's General Transit Feed Specification (GTFS) data hosted by ARC, and the US Census Longitudinal Employer-Household Dynamics (LEHD) dataset for the 10-county Atlanta Region. The GTFS data collected consisted of all the required information preserved and taken care of by the all the relevant transit authority including MARTA, GRTA, Cobb County Transit, Atlanta Streetcar, Gwinnett County Transit, and all other shuttle services. Initially the GTFS data was converted from GTFS to an ArcGIS Network Dataset using the tool Add GTFS to Network Dataset (Morang, 2016).

GTFS data has been a fascinating source of publicly available data to conduct research that highlights public transit and walk accessibility and equity as well. It is standard format for transit services to disseminate transit network information and consists of stops, routes, stop time, and in some cases fare information. Earlier attempts to measure accessibility based on regional travel demand models were not easily accessible to a host of end interest groups involved in transportation research (Karner, 2016). However, GTFS data is publicly available, and gaining a wide range of acceptance for its immense potential to bridge between literatures tied to accessibility concepts and real world of accessibility experience. Gillespie and Fahrenwald (2017) used GTFS data to measure walk access to transit that also incorporated multi-modal access to transit. Blanchard and Waddle (2017) conducted the study using GTFS and pedestrian network data from Open Source Map (OSM) to create a continuous network across all the census block groups of San Francisco Bay area. In addition, cumulative accessibility metric was used at census block levels where employment or job opportunity was treated as the leading variable to estimate accessibility. GTFS data has also been used to do scenario analysis, and measure equity based on hypothetical scenario (Guthrie and et. al., 2017).

OpenStreetMap data was acquired to create the pedestrian accessible street and path network data (e.g. path, stairways, and roads that are not limited access highways) from OpenStreetMap (OSM) acquired to create the pedestrian network. OSM is a free, global, open source, and community edited database of geographic data. Data from OSM was extracted using ArcGIS 10.3. The pedestrian network was used to create service areas with a cut-off point of half mile around transit stops and stations. Creating service areas as opposed to Euclidean buffer prevent over estimation of the aggregate demographics and opportunities.

Employment is used as the main variable to operationalize accessibility and is considered a standard metric in the literature. Employment data from 2013 representing counts of total jobs by industry sector (2-digit North American Industry Classification System (NAICS) code) are acquired from the US Census Longitudinal Employer-Household Dynamics (LEHD) at the block level. Employed resident (worker) and job characteristics for each service area were subsequently aggregated using the LEHD for 2013. Census block centroids falling within each service area were included in the demographic calculations. For this study, three wage categories: low-wage ($less than $1,250 per month), mid-wage ($1,251 - $3,333), and high-wage (greater than $3,333 per month).

Standard ArcGIS network analysis approaches and the ESRI GTFS add-in were used to create the service areas where trip origin and destination were assumed to be transit stop or station associated with service area. A walking speed of 5km/ hour was assumed. Travel times for departures were considered during a two-hour peak period (6:30 – 8:30 am). A cut-off point of 60 minutes of combined walk and transit travel time was used to keep the calculation tractable.
If the travel time between an O-D pair cannot be found considering all route possibilities up to the cut-off time limit, then that O-D pair will not return a travel time value for that pair.

This study used a cumulative opportunity measure of public transit accessibility that returns the sum of each variable's value at each census block that is reachable within a given travel time threshold on the pedestrian and transit network, considering the number of jobs in each income category that can be reached within 60 minutes and is calculated using the following equation:

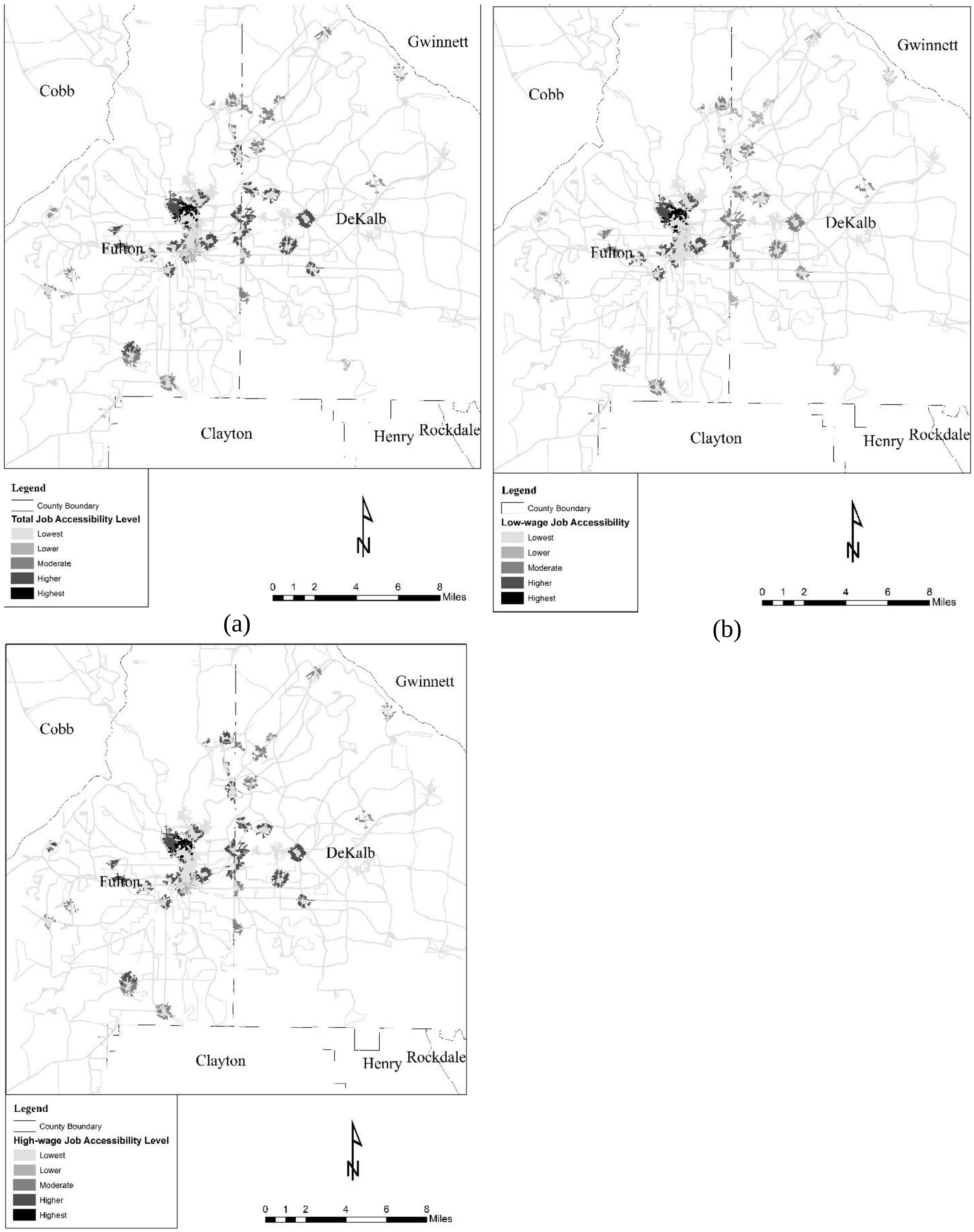
$$A_i^k = \sum_{j,k} p_{ik} E_j^k \text{, where } t_{ij} < T$$

A_i^k = Accessibility at location i for income category k
E_j^k = Number of jobs at location j in income category k
p_{ik} = Proportion of employed residents in location i in income category k
t_{ij} = Travel time (minutes)between locations i and j
T = Travel time threshold (set to 60 minutes)

i and j index the entire set of 9,958 transit stops in the Valley Metro system

Results and Discussion

Figure 2 a shows the results of calculating stop-level cumulative accessibility measures for a 60-minute travel time to all jobs (for all three wage levels). The results predominantly portray the concentration of jobs within the downtown and midtown Atlanta followed by North Druid Hills, located in between Fulton County and Dekalb County, and some parts of Decatur, and northern part of Fulton County. However, this aggregated results of jobs doesn't tell the difference between low-wage job accessibility and high-wage job accessibility. Figure (b) and (c) exhibit the results of stop level cumulative accessibility results for low-wage jobs and high-wage jobs. It is apparently clear from the figure 2b and 2c that high-wage jobs have comparatively better accessibility as opposed to low-wage jobs. Only the downtown area appeared to have highest accessibility for low-wage jobs and a visible drop occurs in all other areas for which job accessibility is as high for the high-wage job as for all jobs categories. Results of figure 2c doesn't show that much variation compared to the figure 2b except for a slight decrease of cumulative accessibility near Decatur and downtown area. Usually, experiencing a higher or the highest level of accessibility in and around the downtown area is quite expected because public transit routes are laid out in a way that can connect as many job as possible i.e. in other words, to maximize the ridership. However, only emphasizing on the location of jobs does not essentially increase ridership because if one the trip ends of home based work trip is missing from consideration, then the route created to connect the job location obviously misses the workers who need access to jobs. Even though the locations of higher concentration of workers seem to be connected with the public transit routes (Figure 1a), but the current frequency and delayed transfer from train to bus or vice versa make the users reluctant to use public transit as well.



(c)

Figure 2: (a)Spatial distribution of Workers using different transport mode to work in 10-County Atlanta Region, (a) Workers drive to work alone, and (c) Workers use public transport.

As it can be seen from figure 3, stop level job accessibility, in general, appears uniform across various wage types. However, for all jobs types accessibility continues to have a sharp increase up to 23rd percentile and then it becomes comparatively steady for the rest. However, job accessibility is marginally higher for the mid-wage job types than the low wage-jobs and even higher for the high-wage job types.

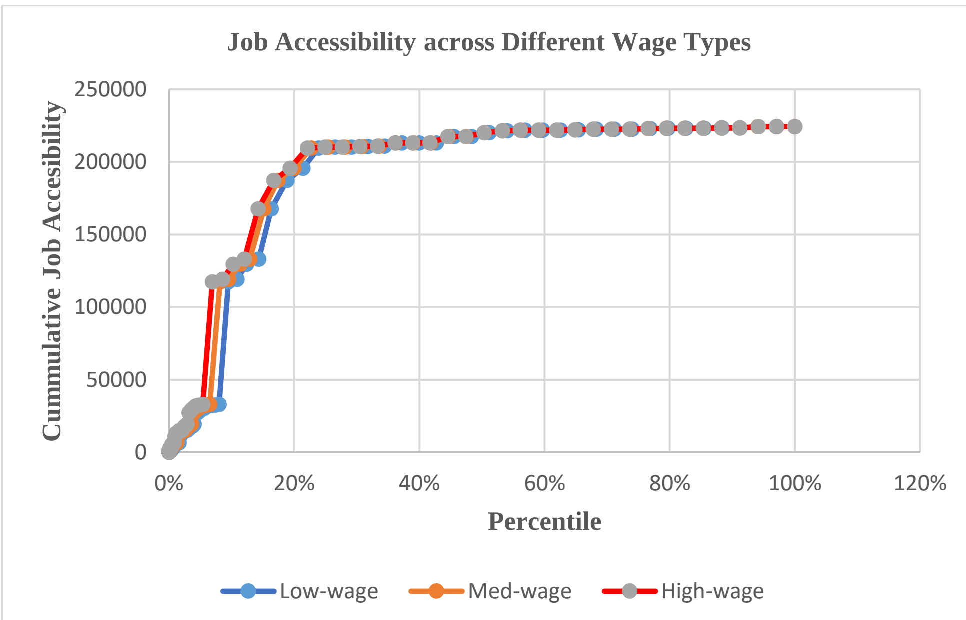


Figure 3: Job Accessibility across Different Wage Types

Each panel in the figure 4 shows one pair of wages: low-mid, mid-high, and low-high. Deviation from a straight line would indicate that some stop provide varying levels of accessibility by wage level. However, the results show that, in general, each stop consistently provides accessibility to all three wage categories – as accessibility increases to jobs in one category the increase for the others, except for a few stops in case of figure 3 (low-wage job accessibility vs. high-wage job accessibility). On the flip side, figure 4 provides some level of inconsistency in stop-level accessibility when the low-wage job accessibility and non-low-wage job accessibility are compared in a logarithmic scale.

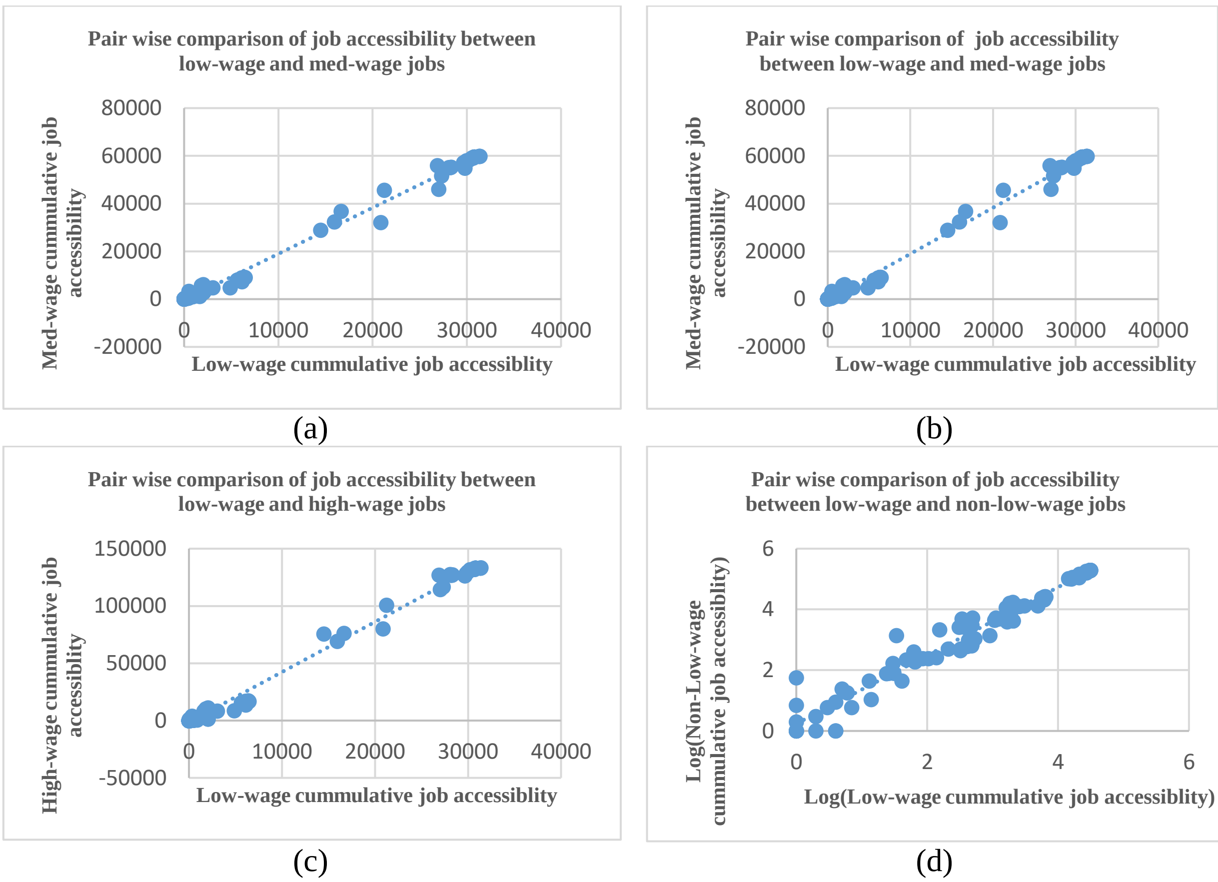


Figure 4: Stop level accessibility to jobs in 10-County Atlanta for three pairwise comparisons by job type: (a) low-wage and mid-wage, (b)low-wage and mid-wage, and (c) low-wage and high-wage.

Conclusion

The study intended to assess stop based public transit accessibility using publicly available, highly detailed GTFS data of 10-County Atlanta region by leveraging the methods developed by Karner (2016). Having a system in place that caters to high levels of aggregate job accessibility by automobile inevitably raise the question of equity. The results of the 10-County Atlanta region accessibility analysis indicate, in general, that transit inequity exists at a small scale across various job types with higher level of job accessibility mostly near the downtown area. While the proportion of workers using public transit to work is significantly lower than the workers who drive alone to work even though many of the high concentration worker location is connected to public transit.

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